APPENDIX 14—OIL AND GAS OPERATIONS

GEOPHYSICAL EXPLORATION

Oil and gas can be discovered by either direct or indirect exploration methods, such as the mapping of rock outcrops, seeps, borehole data, and remote sensing data. In many cases indirect methods, such as seismic, gravity, and magnetic surveys, are required to delineate subsurface features that may contain oil and gas.

Gravity Surveys

Gravitational prospecting detects microvariations in gravitational attraction caused by differences in the density of various types of rock. Gravity data are used to generate anomaly maps from which faults and general structural trends can be interpreted. These surveys are generally not considered definitive, because of the many data corrections required (e.g., terrain, elevation, latitude) and the poor resolution of complex subsurface structures. The instrument used for gravity surveys is a small portable device called a gravimeter. Generally, measurements are taken at many points along a linear transect, and the gravimeter is transported either by backpack, helicopter, or off-road vehicle. The only surface disturbance associated with gravity prospecting is that caused by a vehicle, if used.

Geomagnetic Surveys

Magnetic surveys use an instrument called a magnetometer to detect small magnetic anomalies caused by mineral and lithologic variations in the earth's crust. These surveys can detect large trends in basement rock and the approximate depth to those basement rocks, but in general they provide little specific data to aid in petroleum exploration. Many data corrections are required to obtain reliable information, and the maps generated lack resolution and are considered preliminary. Magnetometers vary greatly in size and complexity. Most magnetic surveys are conducted from the air by suspending a magnetometer under an airplane. Magnetic surveys conducted on the ground are nearly identical to gravity surveys, and surface disturbance is minimal to nonexistent.

Seismic Reflection Surveys

Seismic prospecting is the best and most popular indirect method currently used for locating subsurface structures or stratigraphic variations that may contain oil and/or gas. Seismic energy (shock waves) is induced into the earth using one of several methods. As these waves travel downward and outward, they encounter various rock strata, each having a different seismic velocity. As the wave energy encounters the interface between rock layers, some of the seismic energy is reflected upward. Sensing devices commonly called geophones are placed on the surface to detect these reflections. The geophones are connected to a data recording truck that stores data on magnetic tape. The time required for the shock waves to travel from the shot point down to a given reflector and back to the geophone can be related to depth.

There are many methods available today that an explorationist can use to induce the initial seismic energy into the earth. All methods require preliminary surveying and laying of geophones. The thumper and vibrator methods pound or vibrate the earth to create a shock wave. Usually four large trucks (buggies) are used, each equipped with vibrator pads (about 4 feet square). The pads are lowered to the ground, and vibrators on all trucks are triggered electronically from the recording truck. Information is recorded, then the trucks move forward a short distance and the process is repeated.

Vibrator buggies currently weigh up to 67,000 pounds and have tires up to 4 feet wide. They travel with less surface loading than does a pickup truck. These buggies are spread out from point to point to eliminate leaving a trail. Surface vegetation (including shrubs) is pushed down but not crushed and broken. A small portion of the vegetation is lost due to this action. Observation of a track a year later makes it hard to find where the buggies traveled. Working during winter conditions with snow can cause even less surface damage.

Shothole prospects use drill buggies on rough terrain and drill trucks on flatter landscape. Trucks cause more damage than do buggies. A water truck or buggy may travel with the drill rig. The water is used to keep the hole open while drilling. Small-diameter holes are drilled to depths of 80 to 200 feet. Four to 12 holes are drilled per mile of line. Usually, a 20-pound charge of explosives is placed in the hole, covered, and detonated to generate seismic shock waves. Helicopters may carry a portable drill into rugged terrain. Another portable technique is to carry charges in a helicopter and place them on wooden sticks, or lath, 3 feet or so above the ground. Charges used are either 2 1/2 or 5 pounds. Usually, 10 charges in a line are detonated at once. Seismic lines are aligned relative to the regional structure to make interpretation more accurate.

The geophones and energy source are located along lines on a 1- to 2-mile grid. Although alignment may be fairly critical, spacing of the lines can often be changed 1/4 mile on a 1-mile grid before the results will significantly affect the investigation program.

A typical drilling seismic operation may use 10 to 15 men operating five to seven trucks. Under normal conditions, 3 to 5 miles of line can be surveyed each day using the explosive method. The vehicles used for a drilling program include several heavy truck-mounted drill rigs, water trucks, a computer recording truck, and several light pickups for the surveyors, shothole crew, geophone crew, permit man, and party chief.

Public roads and existing private roads and trails are used. Off-road cross-country travel may be necessary to carry out tasks. Motor graders and/or dozers may be required to provide access to remote areas. Concern about unnecessary surface disturbance has caused government and industry to more carefully plan surveys. As a result, earth-moving equipment is now only rarely used in seismic exploration work. Several trips a day are made along a seismograph line; this usually establishes a well-defined two-track trail. The repeated movement back and forth along the line (particularly the light pickups) defines the trail. Spreading vehicles out so that vehicle routes are not straight and vehicles do not retrace the same route has in some cases prevented the establishment of new trails and has reduced impacts.

A variation on the above techniques is the three-dimensional seismic profile survey. This type of survey differs from the more common survey in the greater number of data points and the closer spacing of the lines. Three-dimensional seismic surveys are more computer intensive but result in a more detailed and informative subsurface picture (with an accompanying higher cost). The orientation and arrangement of three-dimensional seismic surveys are less tolerant of adjustments to the physical locations of the lines and geophones, but they are also more compact in areal extent.

Each of the foregoing methods has inherent strengths and weaknesses, and explorationists must decide which method is the most practical with regard to surface constraints (such as topography) but will still produce information that can be useful for the particular study. Extensive computer processing of the raw data is required to produce a usable seismic section from which geophysicists can interpret structural relationships to depths of 30,000 feet or more. The effective depth of investigation and resolution are determined to some degree by which method is used.

Geophysical Management (Permitting Process)

Geophysical operations are reviewed by the federal surface management agency—the Bureau of Land Management (BLM), the Bureau of Reclamation, or the Forest Service, as appropriate. Good administration and surface protection on geophysical operations can only be accomplished through close cooperation of the operator and the affected agency. The responsibilities of the geophysical operator and the Field Manager are as follows (USDI 1989b):

- Geophysical Operator. An operator is required to file with the Field Manager a Notice of Intent to Conduct Oil and Gas Exploration Operations. The Notice of Intent shall include a map showing the location of the line, all access routes, and ancillary facilities. The operator must be bonded and file evidence of bonding with the notice. Any surface disturbance may require a cultural resources survey and a prework field conference. Earth-moving equipment will only be used with prior approval. Upon completion of operations and rehabilitation, the operator must file a Notice of Completion of Oil and Gas Exploration Operations.
- Field Manager. The Field Manager shall apprise the operator of the practices and procedures to be followed before beginning operations on BLM-administered lands. The Field Manager will consent to bond release once the terms and conditions of the notice have been met.

State Standards

In Wyoming, the operator is required to register with the state. State standards for plugging shotholes, personnel safety, etc., will be followed.

Mitigation

Seasonal restrictions may be imposed to reduce conflicts with wildlife, watershed damage, and hunting activity. Compliance inspections during the operation ensure that stipulations are being followed. Compliance inspections upon completion of work ensure that the lines are clean and the drill holes are properly plugged.

OIL AND GAS LEASING

The Mineral Leasing Act provides that all public lands are open to oil and gas leasing unless a specific order has been issued to close an area. Based on the Federal Onshore Oil and Gas Leasing Reform Act of 1987, all leases must be exposed to competitive interest. Leases are issued for a term of 10 years, or as long as production continues.

The Federal Government receives yearly rental fees on nonproducing leases. Royalty on production is received on producing leases, one half of which is returned to the State of Wyoming.

Drilling Permit Process

A federal lessee or operator is governed by procedures set forth by Onshore Oil and Gas Order No. 1, "Approval of Operations on Onshore Federal and Indian Oil and Gas Leases," issued under 43 Code of Federal Regulations (CFR) 3164. Operating Order No. 1 lists the following as pertinent points to be followed by the lessee or operator: Notice of Staking (NOS); Application for Permit to Drill (APD), which includes a multipoint surface use and operations plan; approval of subsequent operations; well abandonment; water well conversion; responsibilities on privately owned surface; and reports and activities required after well completion.

The federal lessee or operating company selects the location of a proposed drill site. The selection of the site is based on spacing requirements, subsurface geology as interpreted by geologists and geophysicists, topography, and availability of funds for a specific well. Spacing requirements are established by the Wyoming State Oil and Gas Conservation Commission. Each well is to be drilled within a given distance from the center of a legal subdivision. A proposed location may be moved with a spacing exception granted by the Oil and Gas Conservation Commission. Occasionally, BLM may request that a lessee drill a well on the lease if it is determined that federally owned minerals are being drained by an adjacent well on privately owned or state-owned lands (USDI 1981a).

- Notice of Staking. After the company makes the decision to drill, it must decide whether to submit a staking notice or an APD. The NOS consists of an outline of what the company intends to do, including a location map and a sketched site plan. The notice is then used as a document to review any conflicts with known critical resource values, and at the onsite inspection to provide the preliminary data for assessing what additional items are necessary to complete the APD.
- Application for Permit to Drill. Regardless of whether an NOS is filed, the lessee or operator shall file an APD. No surface activity in conjuction with drilling is allowed until the APD is approved. A field inspection is held with the operator and any other interested party. The pre-site field inspection is used to evaluate the operator's plan, assess the situation for possible impacts (surface and subsurface), and formulate resource protection stipulations. To lessen environmental impacts, a site may be moved, reoriented, or redimensioned, within certain limits. The proposed access road may also be rerouted (USDI 1981a).

If necessary, site-specific mitigations are added to the APD for protection of surface and/or subsurface resource values in the vicinity of the proposed well. BLM is responsible for preparing the environmental documentation necessary to satisfy the National Environmental Policy Act (NEPA) requirements and provide any mitigation measures (conditions of approval) needed to protect the affected resource values.

Each APD identifies existing and proposed surface disturbances (such as well pads, roads, pipelines, and surface impoundments) and includes locations of existing wells and water supplies, ancillary facilities, well site layout, and a surface reclamation plan. Operations must be conducted in a manner that minimizes drilling hazards and potential for spills and accidental releases.

Consideration is given to the protection of ground water resources. The geologist is required to identify the maximum depth of usable water as defined in Onshore Oil and Gas Order No. 2.

Usable water is defined as that water containing 10,000 parts per million (ppm) or fewer of total dissolved solids (TDS). Determining the depth to fresh water requires specific water quality data in the proposed well vicinity or geophysical log determination of water quality, depending on existing well proximity and log availability. Water of this quality is to be protected, usually by surface casing and cement.

Operations on leases must also comply with applicable regulations administered by state and local agencies. Development actions must comply with water quality protection requirements of the Upper Colorado River Basin Commission, which effectively control discharges of produced water from petroleum production. Produced water could be surface discharged if it has a TDS of fewer than 5,000 ppm; meets all other chemical, health, land quality, water quality, and safety criteria as outlined in BLM and Department of Environmental Quality (DEQ) guidelines; and has an applicant that has received approval from the DEQ and surface land manager for its use. Surface discharge of produced waters in excess of the applied use would not be allowed. Augmentation of natural flows by discharge of produced water into existing natural channels would not be considered an appropriate use. Excess water would be disposed of in an appropriate manner. If produced waters are disposed of by injection into geologic formation, the native waters of that formation would be of an equal quality to or a lower quality than that of the water being injected.

Once approved, the operator has 1 year to begin construction and drilling operations. If construction does not begin within 1 year, the stipulations must be reviewed before approval of another APD (USDI 1981a).

Surface Disturbance Associated with Exploratory Drilling

Upon receiving approval to drill the proposed well, the operator moves construction equipment over existing roads to the point where the access road will begin. Generally, the types of equipment include dozers (track mounted and rubber tired), scrapers, and motor graders. Moving equipment to the construction site requires moving several loads (some overweight and overwidth) over public and private roads. Existing roads and trails are improved in places, and occasionally culverts and cattleguards are installed if required.

The length of the access road varies. Generally, the shortest feasible route is selected to reduce the haul distance and construction costs. Environmental factors or the landowner's wishes may dictate a longer route. In rough terrain, the type of construction is sidecasting (using the material taken from the cut portion of the road to construct the fill portion); slightly less than one-half of the roadbed is on a cut area, and the rest is on a fill area. Roads are usually constructed with a 14-foot (single lane) or 24-foot (double lane) running surface (in relatively level terrain). Soil texture, steepness of the topography, and moisture conditions may dictate surfacing the access road in some places but generally not for the entire length.

Well locations are constructed differently, but in every case, all soil material suitable for plant growth is first removed from areas to be disturbed and stockpiled in a designated area. Sites on flat terrain usually require little more than removing the topsoil material and vegetation. Drilling sites on ridge tops and hillsides are constructed by cutting and filling portions of the location. It is important to confine extra cut material in stockpiles rather than cast it down hillsides and drainages where it cannot be recovered for rehabilitation.

The level surface needed to assemble and operate a drilling rig varies, but averages 300 by 350 feet. Figure 14 illustrates a typical well location layout. At least 25 feet of cut surface between the drill hole and the edge of the drilling platform is normally needed. This ensures that the foundation of the drilling derrick is on solid ground and prevents it from leaning or toppling due to settling of uncompacted soil. In addition to the drilling platform, an 8- to 12-foot deep reserve pit is usually constructed. Generally, the reserve pit is 8 to 12 feet deep, but it may be deeper to compensate for smaller length and width or deeper drilling depths. Depending on the relation of the location to natural drainages, it may be necessary to construct water bars or diversions.

Moving a drilling rig requires moving 10 to 25 truckloads (some over legal weight and height) of equipment over public highways and private roads. The derrick when erected is approximately 160 feet high.

Water for drilling is hauled to the rig storage tanks or transported by surface pipeline. Water sources are usually rivers, wells, or reservoirs. Occasionally, water supply wells are drilled on or close to the site. The operator must obtain a permit from the Wyoming State Engineer for the use of surface or subsurface water for drilling. When BLM holds the water permits for surface water (stock ponds), we must also approve such use. When drilling begins, and as long as it progresses, water is continually transported to the rig location. Approximately 40,000 barrels, or 1,680,000 gallons, of water is required to drill an oil or gas well to the depth of 9,000 feet.

Issuance of Rights-of-Way

BLM rights-of-way are required for all facilities, tank batteries, pipelines, truck depots, powerlines, and access roads that occupy federally owned land outside the lease or unit boundary. When a third party constructs a facility or installation on or off the lease, a right-of-way is also required.

DRILLING OPERATIONS

Rotary Drilling

Starting to drill is called "spudding in" the well. Initially, drilling usually proceeds rapidly, mainly due to the incompetent nature of shallow formations. While drilling, the rig derrick and associated hoisting equipment bear a great majority of the drill string's weight (Figure 15). The rotary motion is created by a square or hexagonal rod, called a kelly, which fits through a square or hexagonal hole in a large turntable, called a rotary table. The weight on the bit itself is generally a small fraction of the total drill string weight.

Drilling mud is circulated through the drill pipe to the bottom of the hole, through the bit, up the bore of the well, through a screen that separates the rock chips, and into holding tanks from which it is pumped back into the well. The mud is maintained at a specific weight and thickness to cool the bit, reduce the drag of the drill pipe on the sides of the well hole, seal off any porous zones, contain formation fluids to prevent a blowout or loss of drilling fluid, and bring the rock chips to the surface for disposal. Various additives are used in maintaining the drill mud at the appropriate viscosity and weight. Some of the additives are caustic, toxic, or acidic, but these hazardous additives are used in relatively small amounts during drilling operations.

Eventually, the bit becomes worn and must be replaced. To change bits, the entire string of drill pipe must be pulled from the hole, in sections usually about 90 feet long, until the bit is out. The bit is replaced, then the drill string is reassembled and lowered into the hole, section by section, and drilling is started again. The process of removing and reinserting the drilling string uses much of the time required in drilling.

Drilling operations are continuous, 24 hours a day and 7 days a week. The crews usually work three 8-hour shifts or two 12-hour shifts a day. Pickups or cars are used for workers' transportation to and from the site.

Upon completion of the drilling, the equipment is removed to another location. If oil or gas is not discovered in commercial quantities, the well is considered dry. The operator is then required to follow state and BLM policy procedures for plugging a dry hole. The drill site and access road are rehabilitated in accordance with the stipulations attached to the APD (USDI 1981a).

Casing

Various types of casing (steel pipe) are screwed together and placed in the drill hole to keep it open. The casing is cemented in place to protect against fluid movement between the casing and walls of the hole and to keep rocks and the well bore from pushing against the casing and damaging it.

Surface casing that is properly set and cemented also protects surface aquifers from being contaminated by drilling and production operations. Surface casing should be set to a depth greater than the deepest fresh water aquifer that could reasonably be developed. Fresh water may exist at great depths, but these aquifers are not normally considered to be important fresh water sources. Surface casing is large enough to allow subsequent lengths of smaller casing to be set as the well is drilled deeper. Cement is placed to fill the entire void between the pipe and the walls of the hole.

Production casing or liner is intended to provide a conduit for the production of oil and gas so that little or no product is lost in "up-hole zones." Generally, only the bottom few hundred feet of intermediate or production casing is cemented, which often leaves several thousand feet of open hole behind some casing strings. Currently, the operator is only required to cement off "hydrocarbon-bearing zones." Cement is placed across these zones to seal them and to prevent contamination of any water-bearing zones or other porous zones by hydrocarbons.

DEVELOPMENT AND PRODUCTION

Wells are completed and production equipment installed if it is determined that oil or gas is present in commercial quantities. Natural gas is the primary product produced. Completion calls for the installation of steel casing, which is cemented in, to provide stability and to protect specific underground zones. The casing is perforated at the zone containing the oil or gas. Valves and pressure regulators are then installed to control flow of the oil and gas to production facilities.

Pipeline quality gas at the wellhead requires a minimum of processing equipment. As the quality of gas decreases with the increased presence of water, dissolved solids, or liquid hydrocarbons, the amount of processing equipment increases. Water or liquid hydrocarbons in the gas are removed before the gas is mixed with other gas, usually just downstream of the wellhead. If liquid hydrocarbons are present, storage facilities (tank batteries) are required for the liquids until they accumulate in sufficient quantities to be hauled out by large trucks.

Wyoming law prohibits the flaring or venting of natural gas. Exceptions allowed by the Wyoming Oil and Gas Conservation Commission are (1) during testing of a new well or (2) when the amount of gas produced with the oil is so small that pipeline construction is not practical. Otherwise, if a well produces both oil and gas, provisions for shipping the gas must be made before oil production can continue.

The production equipment (separator, holding facility for production water [if any is present], and tank battery) is either placed on a portion of the location (on cut rather than fill) or located a short distance from the wellhead along the access road. Production facility colors are required to be from the standard color chart. The separator and tanks are surrounded by earthen dikes to contain accidental spills. Either all the facilities may be fenced or only the production water pit may be fenced (USDI 1981a).

Oil and Gas Exploratory Units

Surface use in an oil or gas field may be affected by unitization of the leaseholds. In areas of federally owned minerals, an exploratory unit can be formed before a wildcat exploratory well is drilled. The boundary of the unit is based on geologic data. The developers of the unit can enter into an agreement to develop and operate, without regard to separate lease ownerships. All owners share in any well's production and costs are allocated according to agreed-on terms.

Unitization reduces the surface use requirements because all wells are operated as though on a single lease. Duplication of field processing facilities is minimized, because development and operations are planned and conducted by a single operator. Unitization may also involve wider spacing than usual, resulting in fewer wells. Access roads are usually shorter and better organized (USDI 1981a).

It is the general intent of unitization to pool or unitize the interests in an entire structure or area to provide for adequate control of operations, so that development and production can proceed in the most efficient and economical manner, and with minimized environmental impact. Accordingly, each proposal to unitize federally supervised leases must be evaluated upon its specific merits. The unit agreement provides for the exploration, development, and production by a single operator. In effect, the unit functions as one very large lease.

Early consolidation of exploration and development efforts through unitization eliminates the need to drill protective wells (drainage avoidance) within unit boundaries. In a field, each lessee must drill his own well to obtain production and avoid being drained by nearby wells.

Field Development

The most important factor in further development of an oil or gas field is the quantity of production. Other considerations are whether the field is on a lease basis or unitized, the probability of profitable production, the necessity of protecting federal mineral acreage from drainage by off-lease drilling, and the degree to which limits of the field are known.

When a discovery is made, a well spacing pattern must be established before additional development begins. Spacing is regulated by the Wyoming State Oil and Gas Conservation Commission. Well spacing for gas wells is generally at 160 to 640 acres per well and 160 acres or less for coalbed methane. APD procedures for development of wells are the same as those for wildcat (exploration) wells.

New field developments are analyzed in an environmental assessment or an environmental impact statement after the second or third confirmation well is drilled. The operator should then have an idea of the extent of drilling and disturbance required to extract and produce the oil and gas. Many fields go through several development stages. A field may be considered fully developed and produce for several years; later, a deeper pay zone may be discovered that leads to the drilling of more wells. A new state of development can lead to changes in the infrastructure of the field that must be considered for approval by BLM.

As the productive life of a field progresses, problems may arise such as erosion, unvegetated areas, washing out of drainage crossings and roads, plugging of culverts, deterioration of cattleguards, accumulation of derelict equipment, construction of unnecessary roads, unauthorized off-road cross-country travel, and improperly placed or unrehabilitated pipelines. BLM prepares rehabilitation plans to correct these problems and to return the field surface area to its original productivity. Ongoing restoration allows total reclamation to be completed more quickly when a field is finally abandoned (USDI 1981a).

Production

Gas, oil, and water are being produced in the area.

Gas Production

A typical gas well location would consist of a wellhead, methanol injection equipment (to keep production and surface lines from freezing), a separator (which separates gas, oil, and water), a dehydrator (which uses heat and glycol or calcium chloride to extract any water remaining with the gas), and an orifice meter. An intermitter is sometimes used either to shut in the well to build up pressure or to blow the well down if it is being loaded with fluid. If the gas well is producing some oil or condensate, oil tanks are used to store the oil and condensate until it is sold via truck or pipeline.

Water Production

Associated water produced with the oil or gas is disposed of by trucking the water to a DEQ-authorized disposal pit, by placing the water in lined or unlined pits, or through subsurface injection. The quality of the water often dictates the appropriate disposal method.

Production Problems

Weather extremes pose problems for producers by causing roads to become impassable, equipment to malfunction, and freezeup of flowlines, separators, and tanks.

Plugging and Abandonment of Wells

The purpose of plugging and abandoning a well is to prevent fluid migration between zones, to protect minerals from damage, and to restore the surface area. Each well should be handled individually due to a combination of factors, including geology, well design limitations, and specific rehabilitation concerns. Therefore, only minimum requirements can be established, then modified for the individual well.

The first step in the plugging process is the filing of the Notice of Intent to Abandon. This will be reviewed by both the Surface Management Agency and the Rock Springs Field Office (RSFO). The notice must be filed and approved before plugging a well. The operator's plan for plugging the hole is reviewed and must meet the minimum requirements for plugging a well bore, as stated in Onshore Oil and Gas Order No. 2. Oral plugging instructions can be given for plugging current drilling operations, but a notice must be filed after the work is completed. If usable fresh water was encountered while the well was being drilled, the Surface Management Agency will be allowed, if interested, to assume future responsibility for the well, and the operator will be reimbursed for the attendant costs.